Simple Machines

Week 7, Lesson 1

Definition of a Machine
The Principle of Work
Mechanical Advantage
Efficiency of a machine

References/Reading Preparation:

Schaum's Outline Ch. 7

Principles of Physics by Beuche – Ch.5

Simple Machines

Machines: Are devices we use to help us do work.

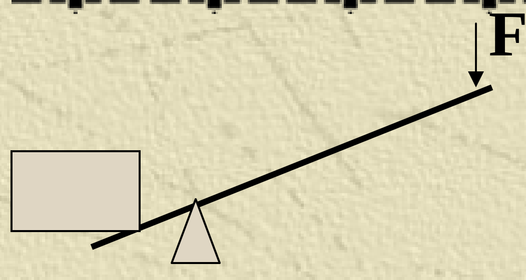
A **Simple Machine:**

Is a mechanical device that can exert a force on an object at one point when an external force is applied to the device at another point.

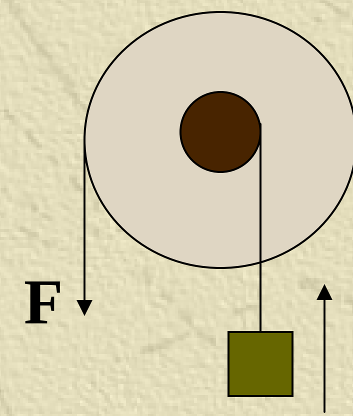
Stated another way, it:

Is any device by which the ***magnitude, direction, or Method of application*** of a force is changed so as to achieve some advantage.

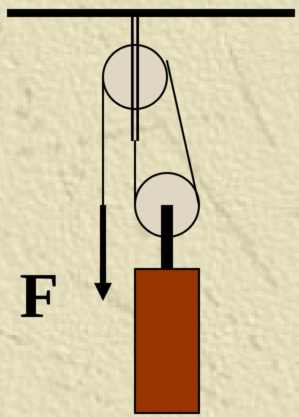
Some examples are:



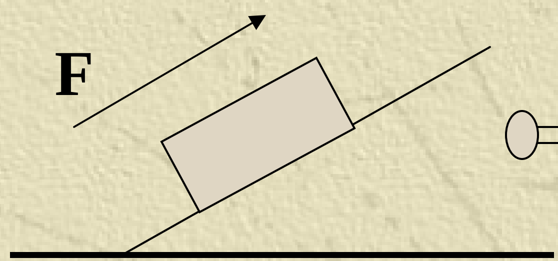
The Lever



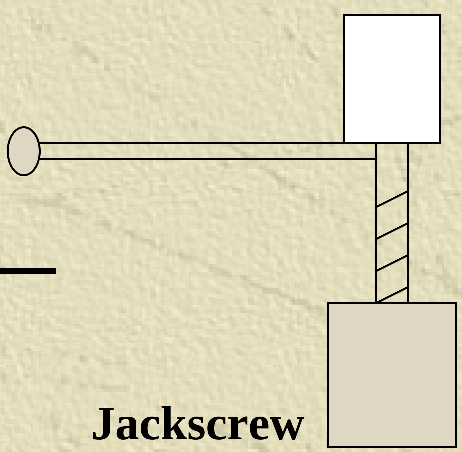
Wheel and Axle



Pulley



Inclined Plane



Jackscrew

Discussion - Machines

Simple machines cannot create energy!

According to the principle of conservation of energy:

-a machine can provide no more work output than the amount of work supplied to it.

In reality, machines are subject to some friction, and so work output is less than work input by an amount equal to the thermal energy produced (by the friction).

The Principle of Work That Applies to a Machine

The **Principle of Work** that applies to a continuously operating machine is as follows:

Work input = useful work output + work to overcome friction

In machines that operate for only a short time, some of the input work may be used to store energy within the machine – for example, an internal spring may be stretched.

Efficiency of a Machine

The ***efficiency*** of a machine measures the degree to which it converts work input to work output.

$$\%\ \text{efficiency} = \frac{\text{work output}}{\text{work input}} \times 100$$

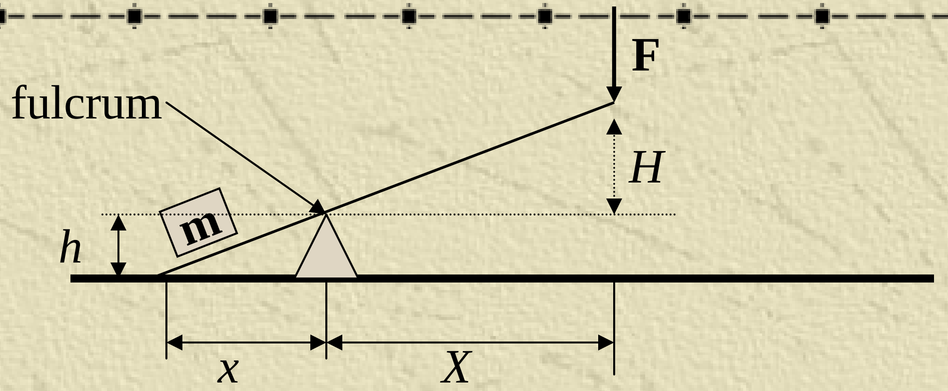
If a machine could operate at 100% efficiency, it would be called an ***ideal*** machine.

Mechanical Advantage

Although machines cannot create energy, they can magnify the input force.

Consider the lever:

A force **F** is applied to raise the mass m a distance h.



The work done by F to do this = work input = FH

The weight mg is lifted through a displacement h.

Thus, Work output = mgh

We assume that there is no friction at the fulcrum, so that we are dealing with an ideal machine.

Thus, work input = work output or $FH = mgh$ or $F = mgh/H$

From similar triangles, $h/H = x/X$ therefore $F = mgx/X$

The Mechanical Advantage (cont'd)

$F = mgx/X$

This equation tells us that, to lift a load, we need to exert a force F that is less than mg by the ratio x/X..

For example: if $x = ½ X$, then F would have to be only ½ mg.

The lever has thus multiplied the input force by 2!!

We call the ability of a simple machine to multiply forces the ***mechanical advantage*** of the machine.

Actual Mechanical Advantage

If F_o is the force output of the machine,

and

F_i is the force applied (the input force),   Then we define

$$\textbf{Actual Mechanical Advantage (AMA)} = \frac{F_o}{F_i}$$

In the case of our lever, with $x = ½ X$, then

$F_o = mg$ and $F_i = ½\, mg$ **Therefore, AMA = 2**

The price you pay for magnifying a force with a simple machine is that the distance through which the load is moved is shorter than the distance through which you exert the applied force!!

Ideal Mechanical Advantage

As we saw, the distance moved by F_i is greater than the output force F_o.

This difference in distance is simply a consequence of the conservation of energy.

Thus, for an *ideal* machine, $F_i s_i = F_o s_o$

where s_i is the distance over which the applied force is exerted, and
s_o is the distance the load is moved

The mechanical advantage of an ideal machine can be expressed as the ratio of the input and output displacements:

Ideal Mechanical Advantage (IMA) = s_i / s_o

Example

A motor furnishes 120 hp to a device that lifts a 5000 kg load to a height of 13.0 m in 20 s. Compute a) the work output, b) the power output and power input, c) the efficiency of the system.

Examples

In the figure, the 300N load is balanced by a force F in both systems. Assuming efficiencies of 100%, how large is F in each system? Assume all ropes are vertical.